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# Wideband Spectrum 700-1300MHz Occupancy and Ranking

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## Abstract

Spectrum occupancy is the most important communications issue which takes a great deal of attention from communication researchers. In this paper a wide spectrum occupancy measurement campaign is conducted to study the occupancy of Radio Frequency (RF) spectrum by three stations at different locations in Bahrain. The measurements are performed in the frequency bands (700-1300) MHz over 10 consecutive days. The results of measurement showed that the spectrum occupancy was almost the same in the three locations. In addition to this, the general usage of frequency regardless the location is considered low except for the frequency band (942–960) MHz slot is classified as rank 1 with frequency occupancy percentage 100%, followed by frequency band (890-942) MHz, which is classified as rank 2, with frequency occupancy 65.36%, these two bands used for the mobile telecommunication provided by the commercial Global System Mobile (GSM) operators, there are 6 bands with occupancy less than 15%. These sub-bands should be reconsidered for more efficient utilization. The Cognitive Radio Spectrum is needed that enables cognitive radio systems to intelligently utilize the spectrum.

## Keywords

Spectrum Occupancy, Mobile Telecommunication, Spectrum Utilization, Cognitive Radio

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## 1. Introduction

Radio frequency is an important and valuable natural resource; electromagnetic spectrum is part of the frequency band. The radio frequency band is limited nature resources; therefore utilization of this resource efficiently is one of the important issues of telecommunication technologies. The nations must apply regulation to monitor, secure, and manage the using of the radio frequency. The radio frequency of each country must be agreed with the whole world telecommunication regulations.

Many communication services utilizes their allocated bandwidth partially during the 24 hours of the day (Qaraqe et al, 2010). As an example of that, a delivery service may have a land mobile license that covers a certain region within a city and yet they may only use their licensed band during the working hours only for their business.

Due to the fact that there is a finite span of the spectrum that is usable by communication services, numerous studies have examined the efficiency of the usage of the licensed bands. Those studies aimed at helping the regulatory authorities to rethink the spectrum licensing policies with the objective of utilizing the spectrum of licensed prime users to allow unlicensed secondary usage (Blackmanand and Srivastava, 2011).

This paper aimed to measure radio spectrum bands (700-1300) MHz occupancy for three locations in Bahrain for a period of 10 days. The paper divided into sections for; radio frequency spectrum, related studies, data collection and analysis, and conclusion.

## 2. Radio Frequency Spectrum

The Radio Frequency spectrum (RF spectrum) defined as the

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part of the electromagnetic spectrum that has limited range from 0 Hz up to 3000 GHz. The frequency spectrum is a limited natural resource that cannot be owned by any nation of organization, but can only be shared amongst various countries, services, users, and technologies (NTIA, 2004). The limitation of the radio frequency spectrum usage depends on several factors such as availability of equipment, technology, propagation, operational constraints, and suitability of different frequencies for specific applications (Australian government, 2011).

There are many application uses the radio frequency spectrum as a resource. The radio frequency spectrum usage is varied from one application to another, where several applications can work on any frequency band, some applications can work on different frequencies, but in a specific band and other applications can work on different variety ranges of the spectrum (ACMA, 2011).

Spectrum management takes very important place in the agenda of regulation in developing countries since wireless is the most popular technology in these countries (ICT Regulation Toolkit, 2012). According to International Telecommunication Union (ITU) recommendations the spectrum management functions are classified as spectrum planning, engineering, authorization, and monitoring.

The spectrum monitoring helps the spectrum managers in avoiding incompatible usage and prevent interference and in identifying harmful interference sources. It provides the spectrum occupancy and information about the technical and operational nature (ICT Regulation Toolkit, 2012).

## 3. Related Studies

There are many studies related to the frequency spectrum occupancy. In Ireland, Erpek et al, (2007-a) conducted their study that summarized the results of the spectrum occupancy measurements was made by Shared Spectrum Company at the Commission for Communications Regulation Building, Dublin, Ireland. Measurements were made in the frequency bands of the range (30-3000) MHz. Their results showed that there are signal overload and/or inter-modulation effects in the data that would tend to increase the measured occupancy compared to the real occupancy. In another study Erpek et al, (2007-b) conducted their study in USA to summarize spectrum occupancy measurements, which was made by Shared Spectrum Company at the Loring Commerce Centre, Limestone, Maine over the frequency ranges from 30MHz up to 3000MHz. The results showed that the occupancy levels are close to the lowest location that Shared Spectrum Company has measured. There were no strong emitters in the nearby area. These features made Loring Commerce Centre an ideal location for testing wireless systems.

In Singapore, Islam et al, (2008) studied the 24-hour spectrum used for the frequency (80-5850) MHz. The measurements were over 12 weekday periods revealed that the amount of spectrum in Singapore had a very low occupancy all the time. The results indicated that most of the allocated frequencies are heavily underutilized, except for the frequency bands allocated for broadcasting and cell phones. The average occupancy for the whole range of the frequency of their study was found only 4.54%.

In Indonesia Ismail et al, (2009) calculated spectrum utilization on user side and provider side. Their measurement showed that the provider used many spectrums in Jakarta and Jawa to serve their customers. This made the spectrum utilization in Jakarta and Jawa the highest compared to any other location.

In Spain, López-Benítez et al, (2009) presented spectrum occupancy measurements conducted for the frequency range (75-3000) MHz in an outdoor environment in urban Barcelona. The occupancy results indicated that spectrum experiences a relatively high use below 1000MHz, while remained underutilized in the range (1000-3000) MHz. Another study by López-Benítez et al (2010-a), which conducted spectrum measurement campaign over a rich diversity of measurement scenarios including high points, indoor and outdoor locations in an open area and between buildings at the ground level in order to determine, analyze and quantify the spectral activity perceived by a cognitive radio user. They developed and verified a theoretical model for the observed occupancy levels, which measured in different locations. The overall results illustrated that the frequency occupancy levels perceived by secondary users were strongly depended on the location with significant variations.

López-Benítez et al, (2010-b) continued their studies and presented a comprehensive and in depth discussion of several important methodological aspects for evaluating the radio spectrum occupancy. Moreover, they had provided and applied a quantitative evaluation and a guideline for the factors that obtained the results. Finally, they recommended the analysis of the spatial dimension of their future work.

In *State of Qatar*, According to Qaraqe et al, (2010) a wideband spectrum occupancy measurement campaign was conducted to study the utilization of radio frequency spectrum in indoor and outdoor environments simultaneously. The measurements were performed for the 700-3000 MHz frequency band over 3 consecutive days in an indoor and an outdoor location concurrently. The results showed the only observed strong channels are in the range (950-1800) MHz corresponding to the downlink (base station to mobile station) transmissions of GSM900 and 1800 and are due to the indoor

solution in place by one of the operators.

In *Romania*, Martian et al, (2010) conducted measurement campaigns in Bucharest for the frequency band (25-3400) MHz. The results showed that the mean of the frequency occupancy over the whole measured frequency band was 12.19%, which considered as a low utilization of the spectrum.

In the *UK*, Harrold et al, (2011) described the results of long term spectrum occupancy measurements for the frequency band (300-4900) MHz at one location over the period of 6 months in order to discover the applicable frequency channels for cognitive radio use on a time interleaved basis. The results of the measured channels were categorized according to their duty cycle in which the frequency range below 500 MHz and between 1 GHz and 1.2 GHz considered a duty cycle between 10 % and 90%. Another study was conducted by Mahdawi et al., (2013) which performed a set of radio frequency spectrum occupancy measurements at University of Hull-UK in November 2012 for the frequency bands (180-2700) MHz, which was a long term study in one location. The results showed a low utilization; the average of the frequency occupied for the whole frequency band was 11.04% that was an evidence for the decision makers to improve the spectrum efficiency by using sharing techniques which enables the reuse of the available frequency spectrum dynamically.

In *south china*, Liang et al, (2012), conducted concurrent spectrum occupancy measurement to evaluate the usage of the radio spectrum over the frequency band (20-3000) MHz in 4 different locations. They had used systematic spectrum measured methodology, matrix format data storage, Duty Cycle evaluation metric and data mining process. The results showed significant amount white spaces, especially in the TV band White Space, which applies to the future cognitive radio's applications. Furthermore, they recommended conducting spectrum occupancy measurement with high-time resolution and long time periods in order to obtain a realistic and accurate spectrum occupancy model in the future studies.

In Urban et al, (2012) introduced radio spectrum survey measurement system to focus on the wideband and fast spectrum scans performed in different locations. They analyzed the results of the utilization of the frequency spectrum, which was underutilized in most of the measured frequency bands, in order to prove the underutilization and to show the frequency spectrum sharing possibilities. Finally, they recommended using spectrum sharing technique such as cognitive radio technique for the usage of frequency bands which was around 5%.

In Germany, Wellens et al, (2007) conducted measurement to compare indoor and outdoor measurement results. Since an energy detector cannot differentiate such noise from other primary user signals they determined very high spectrum occupancy in the outdoor scenario in the bands (20-3000) MHz. Considerably less occupation was measured in the indoor scenario also because of less ambient noise. The measurements confirmed that the spectrum bands (3-6) GHz are rarely occupied. In the outdoor campaign unexpectedly high level of ambient or man-made noise led to a spectrum occupancy of nearly 100% for 20MHz to 3 GHz. In 2010 Wellens et al, continued their studies and conducted several measurement campaigns in three stations for the frequency bands from (20-6000) MHz, and introduced a new model for the duty cycle distribution in order to investigate spectrum usage changes over 5 days.

## 4. Data Collection and Analysis

Quantitative method was used in this research by using the Long Term measurement technique to measure the frequency occupancy of the wideband frequency spectrum for 24 hours from 9:00am to 9:00am the next day for 10 days. The number of measurements in the three stations was 24008 readings per day for 10 bands from 700 to 1300 MHz (NFP, 2009). Table (1) shows the number of readings for these sub bands.

**Table 1.** Frequency bands, readings for each day

| No | Frequency bands (MHz) | No. of readings |
|---|---|---|
| 1 | 700-790 | 3601 |
| 2 | 790-825 | 1401 |
| 3 | 825-862 | 1481 |
| 4 | 862-890 | 1121 |
| 5 | 890-942 | 2081 |
| 6 | 942-960 | 721 |
| 7 | 960-1164 | 8160 |
| 8 | 1164-1215 | 2040 |
| 9 | 1215-1240 | 1001 |
| 10 | 1240-1300 | 2401 |
| Total | | 24008 |

The table shows the number of measurement readings for each of the three stations is 24008 readings with a rate of 17 readings/min each day, and the total readings for the 10 days are 240080 readings for each station.

Frequency band capacity is the maximum amount of the frequencies that can be contained in the frequency band. The frequency band capacity measured by (R&S user manual, 2011);

$$\text{Frequency band capacity} = \text{upper frequency in KHz} - \text{lower frequency in KHz} + \text{channel} \quad (1)$$

$$\text{No of readings} = \text{frequency band capacity} / \text{channel} \quad (2)$$

*Example*: in the first row of Table (1) the frequency band (700-790) MHz the capacity of this band is 90 MHz plus one

channel which is 90.25 (channel is 25KHz in the measurement setup), and number of readings by applying equation (2).

No of reading =9025/25=3610 Frequency band (700-790) MHz

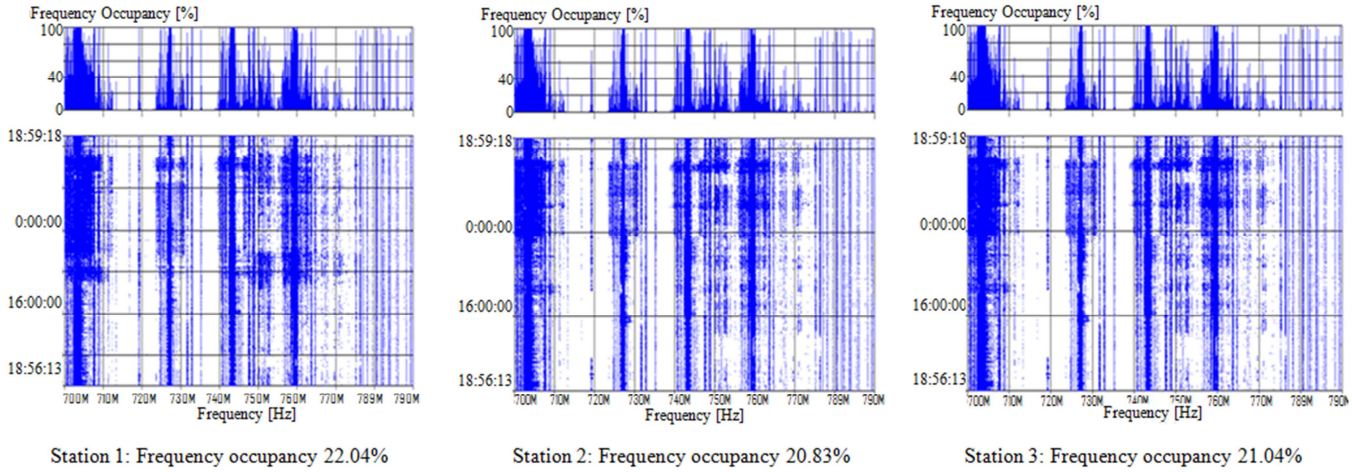


**Figure 1.** First day frequency occupancy to band (700–790) MHz

Figure (1) shows the measurements of occupancies on the first day of the frequency band 700 – 790 MHz to the three stations. This frequency band is regionally licensed for both broadcasting and land mobile use, which is for broadcasting band IV/V, analog and digital TV. The upper part of this figure is for frequency occupancy, which shows frequency along the x-axis and frequency occupancy values in (%) along the y-axis. The lower part of the figure shows the frequency along the x-axis and time along the y-axis. The frequency occupancy measured by (R&S user manual, 2011):

Occupied frequency band = (occupied percentage*frequency band capacity)/100 (3)

Frequency occupancy % = (Number of measured values≥threshold/Total number of measured values)*100 (4)

Frequency band (790–825) MHz.

Figure (2) shows the measurements of the frequencies of this band. This frequency band regionally licensed for both fixed and mobile except aeronautical mobile and broadcasting uses.

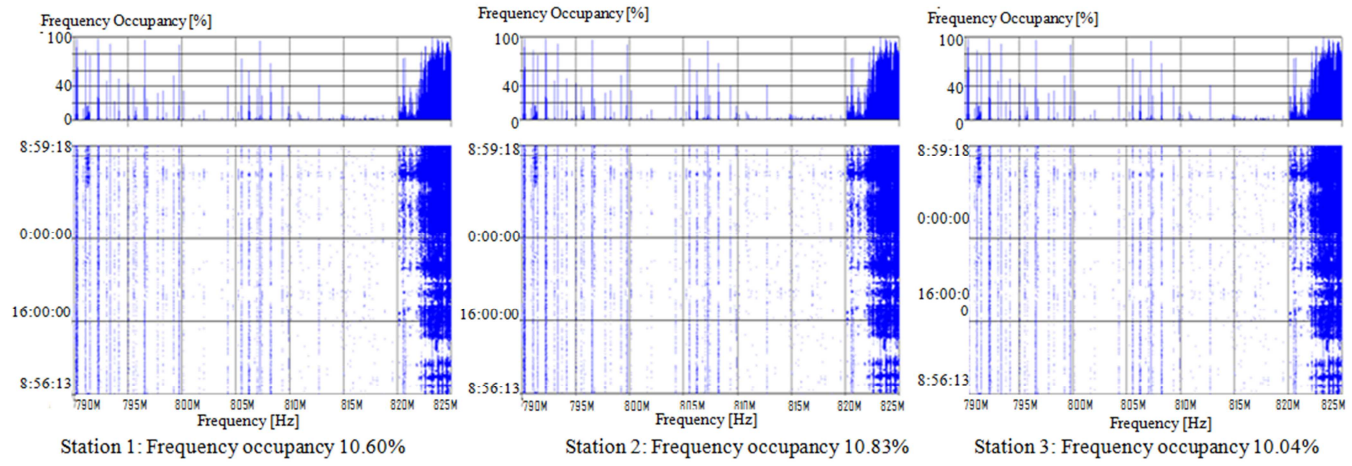


**Figure 2.** First day frequency occupancy to band (790 – 825) MHz

From the figure, it is obvious that most of the frequency band is not utilized except around the 825MHz. This indicates that this frequency band should be reconsidered for proper planning. Frequency band (825–862) MHz.

Figure (3) shows the measurements of the frequencies of this band. This frequency band is regionally licensed for both of fixed, mobile except aeronautical mobile and broadcasting uses as the frequency band (825–862) MHz.

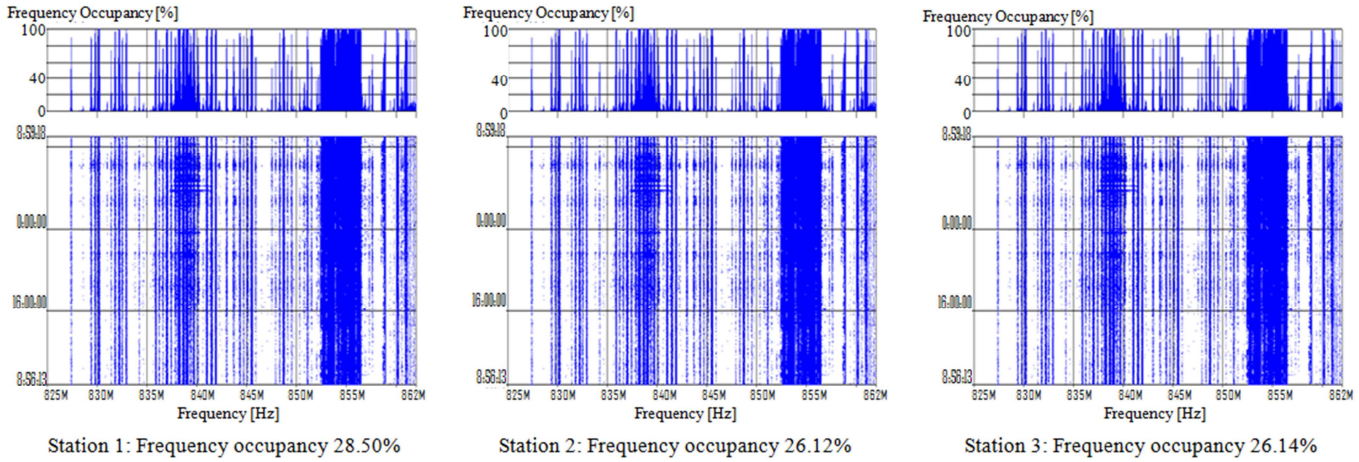


**Figure 3.** First day frequency occupancy to band (825–862) MHz

From the figure it is obvious that there are several frequent gaps that are not occupied in this frequency band. For example, there is an obvious frequency gap 825MHz to 829MHz. Another frequency gap is 845 MHz and 857 MHz. On the other hand, the almost fully utilized frequency bands are those in the frequency range of (837–841) MHz, and (852–857) MHz, however the frequency band (790-862) MHz is planned to be used for broadband services (e.g. LTE) in all GCC countries and it will re-planned based on that where all broadcasting channels will be migrated. Frequency band (862–890) MHz.

Figure (4) shows the measurement of frequency occupancy of this band. This frequency band regionally licensed for fixed, mobile except aeronautical mobile use, and part of this frequency band (862-870) MHz is licensed for Short Range Devices (SRD) and the frequency band (876-890) MHz is planned to be used for the GCC Railway Project.

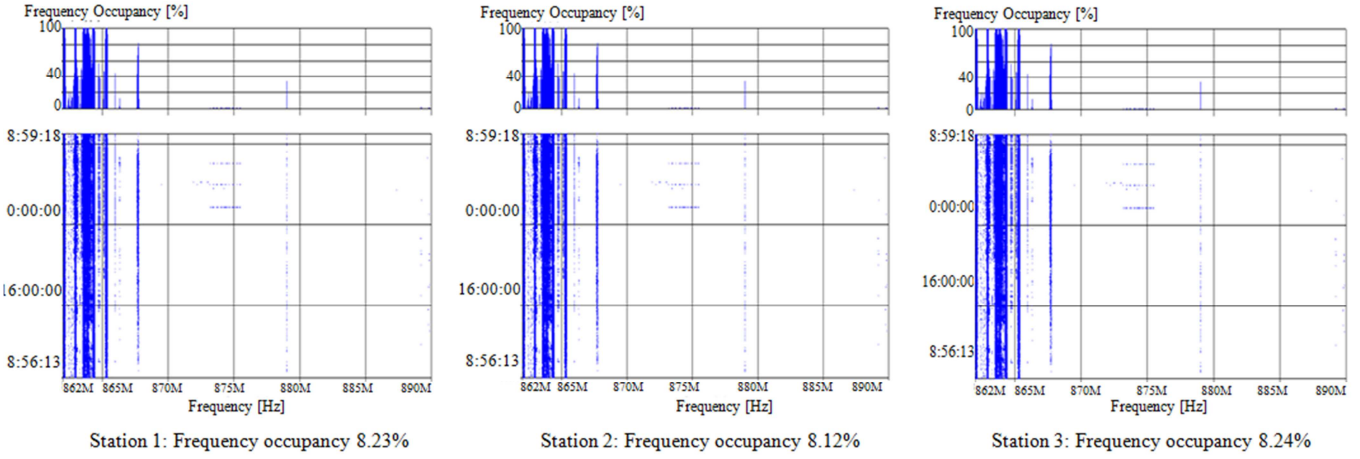


**Figure 4.** First day frequency occupancy to band (862–890) MHz

The figure shows that this frequency band is almost unoccupied except for the frequency range from 862 MHz to 866 MHz. This indicates that this frequency band should be reconsidered for proper planning with consideration of the Short Range Devices (SRD) Service. Frequency band (890–942) MHz.

Figure (5) shows the measurement of frequency occupancy of this band. This frequency band regionally licensed for fixed, mobile except aeronautical mobile use. This frequency band is used and occupied by the mobile operators for GSM and EGSM 900 systems.

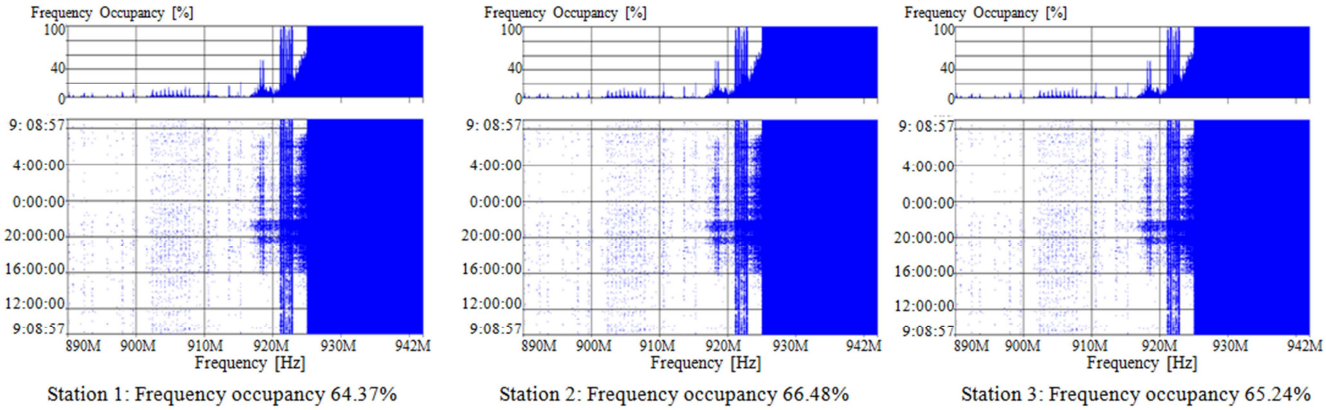


**Figure 5.** First day frequency occupancy to band (890–942) MHz

The figure shows that this frequency band is divided into two, one for the frequency range from 890 MHz to almost 921 MHz, which used for GSM handheld set transmitters with less than 2Watts (low power), and the other frequency ranges from 921MHz to 942MHz which is used for GSM base stations transmitters. Frequency band (942–960) MHz.

Figure (6) shows the measurement of frequency occupancy of this band. This frequency band regionally licensed for fixed, mobile except aeronautical mobile use. This frequency band is used and occupied by mobile operators for a GSM 900 system.

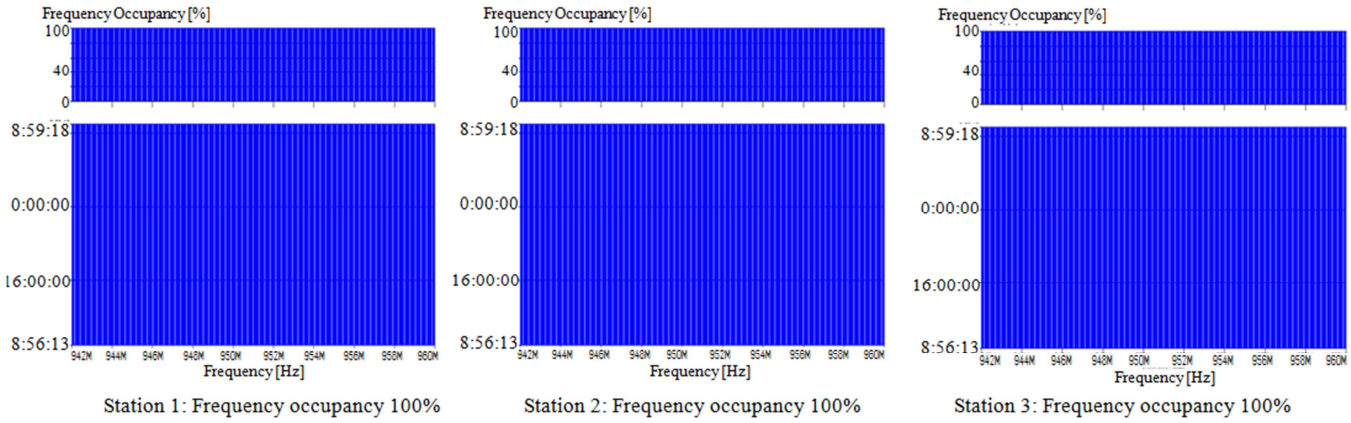


**Figure 6.** First day frequency occupancy to band (942–960) MHz

From the figure, it is obvious that this frequency band is fully utilized. This is expected because this frequency band is used for commercial operations of the mobile operators, especially for the GSM base station transmitters. Frequency band (960–1164) MHz.

Figure (7) shows the measurement of frequency occupancy of this band. This frequency band is licensed for government and civil aeronautical radio navigation, DME landing, ground replay, and interrogation use.

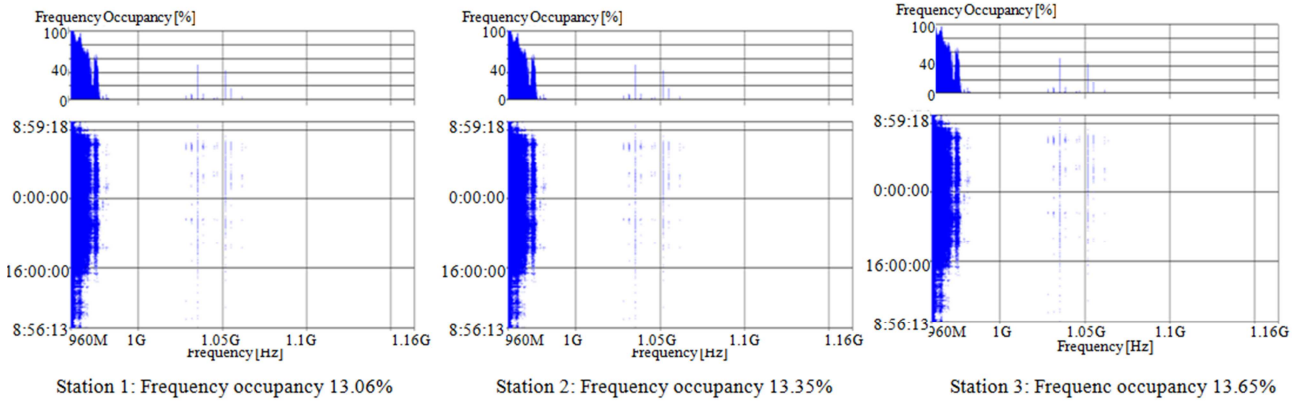


**Figure 7.** First day frequency occupancy to band (960–1164) MHz

From the figure, it is obvious that this frequency band is almost unoccupied except for the frequency range from 960 MHz to 980 MHz. This frequency band should be reconsidered for proper planning with consideration of the real usage of this frequency band. Frequency band (1164–1215) MHz.

Figure (8) shows the measurement of frequency occupancy of this band. This frequency band is licensed for government and civil aeronautical radio navigation use.

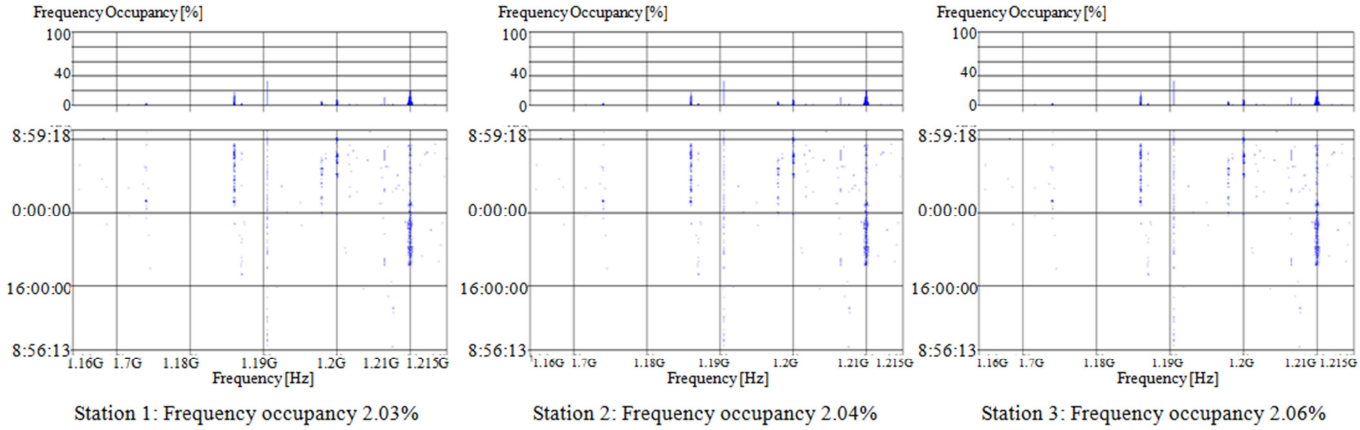


**Figure 8.** First day frequency occupancy band (1164–1215) MHz

From the figure, it is obvious that this frequency band is almost unoccupied or not utilized. This is expected due to the nature of the propagation of this frequency band and due to the usage of the agencies who own the license – Government. However, this frequency band should be reconsidered for proper planning with consideration of the real usage of this frequency band since the measurements did not show the actual use of this frequency band due to its propagation factors. Frequency band (1215–1240) MHz.

Figure (9) shows the measurement of frequency occupancy of this band. This frequency band is licensed for DME landing \ground reply\interrogation use.

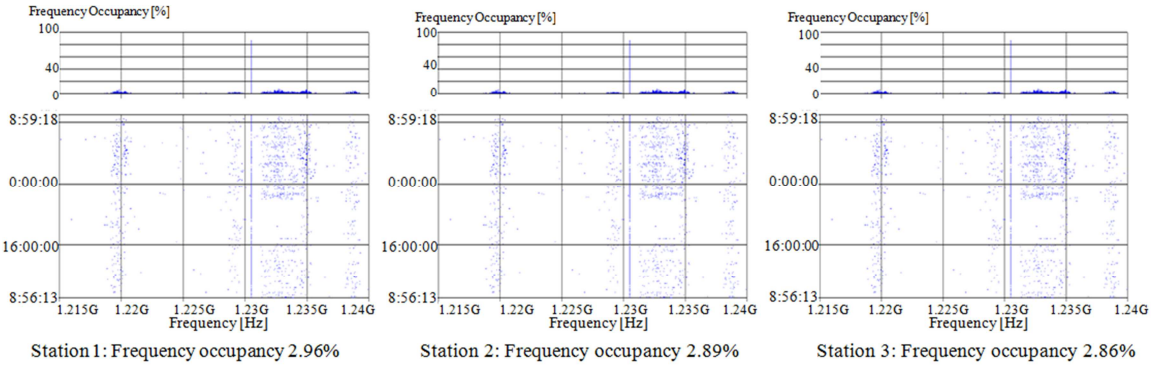


**Figure 9.** First day frequency occupancy to band (1215–1240) MHz

From the figure, it is obvious that this frequency band is almost unoccupied or not utilized. This is expected due to the nature of the propagation of this frequency band and due to the usage of the agencies who own the license – Government. Frequency band (1240 – 1300) MHz

Figure (10) shows the measurement of frequency occupancy of this band. This frequency band is licensed for government and private use for radio location and radio navigation-satellite.

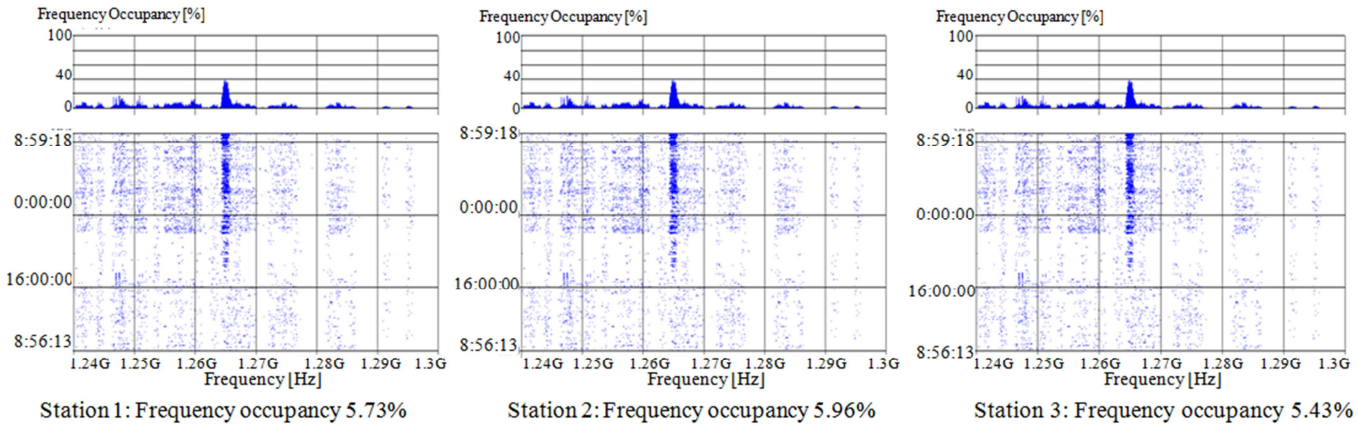


**Figure 10.** First day frequency occupancy to band (1240 – 1300) MHz

From the figure, it is obvious that this frequency band is almost unoccupied except for the frequency range around 1265 MHz, while the rest of the frequency band is almost not utilized. Table (2) shows the frequency occupancy for three stations.

**Table 2.** Frequency occupancy percentage for the three stations along with the allocated licenses

| Frequency bands (MHz) | Location 1 occupied (%) | Location 2 occupied (%) | Location 3 occupied (%) | Average (%) of the 3 stations | Rank |
|---|---|---|---|---|---|
| 700-790 | 22.04 | 20.83 | 21.04 | 21.30 | 4 |
| 790-825 | 10.6 | 10.83 | 10.04 | 10.49 | 6 |
| 825-862 | 28.5 | 26.12 | 26.14 | 26.92 | 3 |
| 862-890 | 8.23 | 8.12 | 8.24 | 8.20 | 7 |
| 890-942 | 64.37 | 66.48 | 65.24 | 65.36 | 2 |
| 942-960 | 100 | 100 | 100 | 100.00 | 1 |
| 960-1164 | 13.06 | 13.35 | 13.65 | 13.35 | 5 |
| 1164-1215 | 2.63 | 2.34 | 2.16 | 2.38 | 10 |
| 1215-1240 | 2.96 | 2.89 | 2.86 | 2.90 | 9 |
| 1240-1300 | 5.73 | 5.96 | 5.43 | 5.71 | 8 |

The table shows that, the rank 1 was for the frequency band (942-960) with frequency occupancy 100%, rank 2 was for the frequency band (890-942) with frequency occupancy 65.36%, rank 3 was for the frequency band (825-862) with frequency occupancy 26.92%, rank 4 was for the frequency band (700-790) with frequency occupancy 21.30%, rank 5 was for the frequency band (960-1164) with frequency occupancy 13.35%, rank 6 was for the frequency band (790-825) with frequency occupancy 10.49%, rank 7 was for the frequency band (862-890) with frequency occupancy 8.20%, rank 8 was for the frequency band (1240-1300) with frequency occupancy 5.71%, rank 9 was for the frequency band (1215-1240) with frequency occupancy 2.90%, and finally rank 10 was for the frequency band (1164-1215) with frequency occupancy 2.38%, the average frequency occupancy to all the bands of the wideband 700-1300 MHz is 25.66%, which is underutilization.

## 5. Conclusion

The main objective of this paper is to find out how the scare radio spectrum allocated to different services. And identify the bands that can be accessed for future use due to the low or no active utilization. It is known that the current technology used for telecommunication applications utilize the frequency range from 700 MHz to 1300 MHz; therefore, the radio frequency occupiers for the bands ranges from 700 MHz to 1300 MHz were measured. In this paper the frequency occupancy classified as; above 80% is *very high,* from 79-60% is *higher,* from 59 - 40% is a *middle*, from 39 - 20% is *low*, and less than 20% is *very low*. Therefore the results of the frequency bands occupancy classified as in Table (3).

**Table 3.** Classification of the frequency occupancy

| Frequency bands (MHz) | Average (%) of the occupancy | Degree of occupancy |
|---|---|---|
| 700-790 | 21.30 | Low |
| 790-825 | 10.49 | Very Low |
| 825-862 | 26.92 | Low |
| 862-890 | 8.20 | Very Low |
| 890-942 | 65.36 | High |
| 942-960 | 100.00 | Very High |
| 960-1164 | 13.35 | Very Low |
| 1164-1215 | 2.38 | Very Low |
| 1215-1240 | 2.90 | Very Low |
| 1240-1300 | 5.71 | Very Low |

According to the table, it can be found that the occupancy for most of the frequency bands are low or very low, except for the band (942–960) MHz, which is used for commercial mobile services with occupancy 100%. The next highest occupancy is for band (890–942) MHz, which is partially used for commercial mobile services. The results indicate that there are 6 bands with occupancy less than 15%. These sub-bands should be reconsidered for planning again.

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